Fig. 1

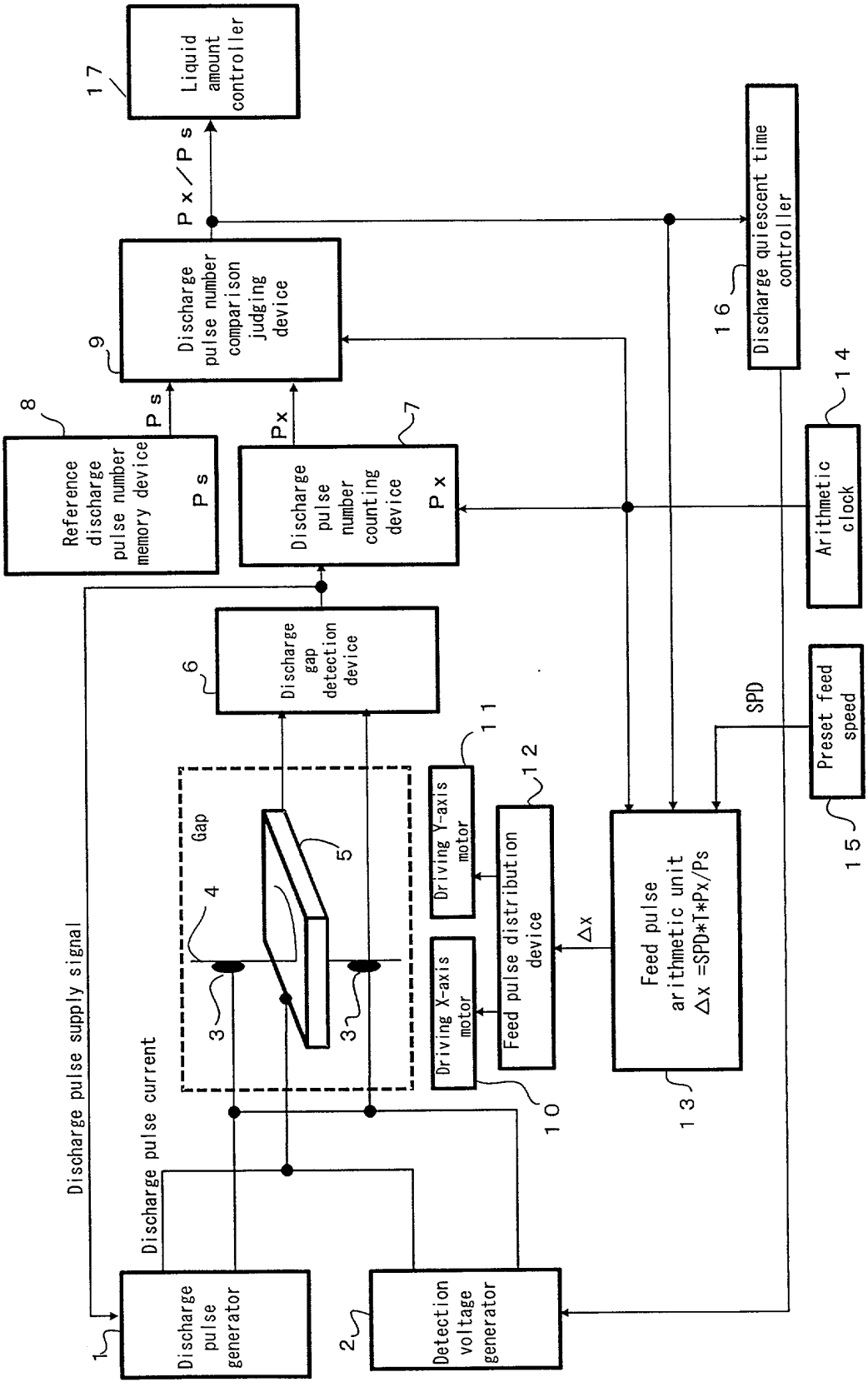

17
Liquid amount controller
Px／Ps
9
Discharge pulse number comparison judging device
16
Discharge quiescent time controller
8
Reference discharge pulse number memory device
Ps
Ps
Px
7
Discharge pulse number counting device
Px
14
Arithmetic clock
6
Discharge gap detection device
11
Driving Y-axis motor
12
Feed pulse distribution device
Δx
Feed pulse arithmetic unit Δx =SPD*T*Px/Ps
13
SPD
Preset feed speed
15
Gap
4
5
3
3
Driving X-axis motor
10
Discharge pulse supply signal
Discharge pulse current
1
Discharge pulse generator
2
Detection voltage generator

Fig. 2

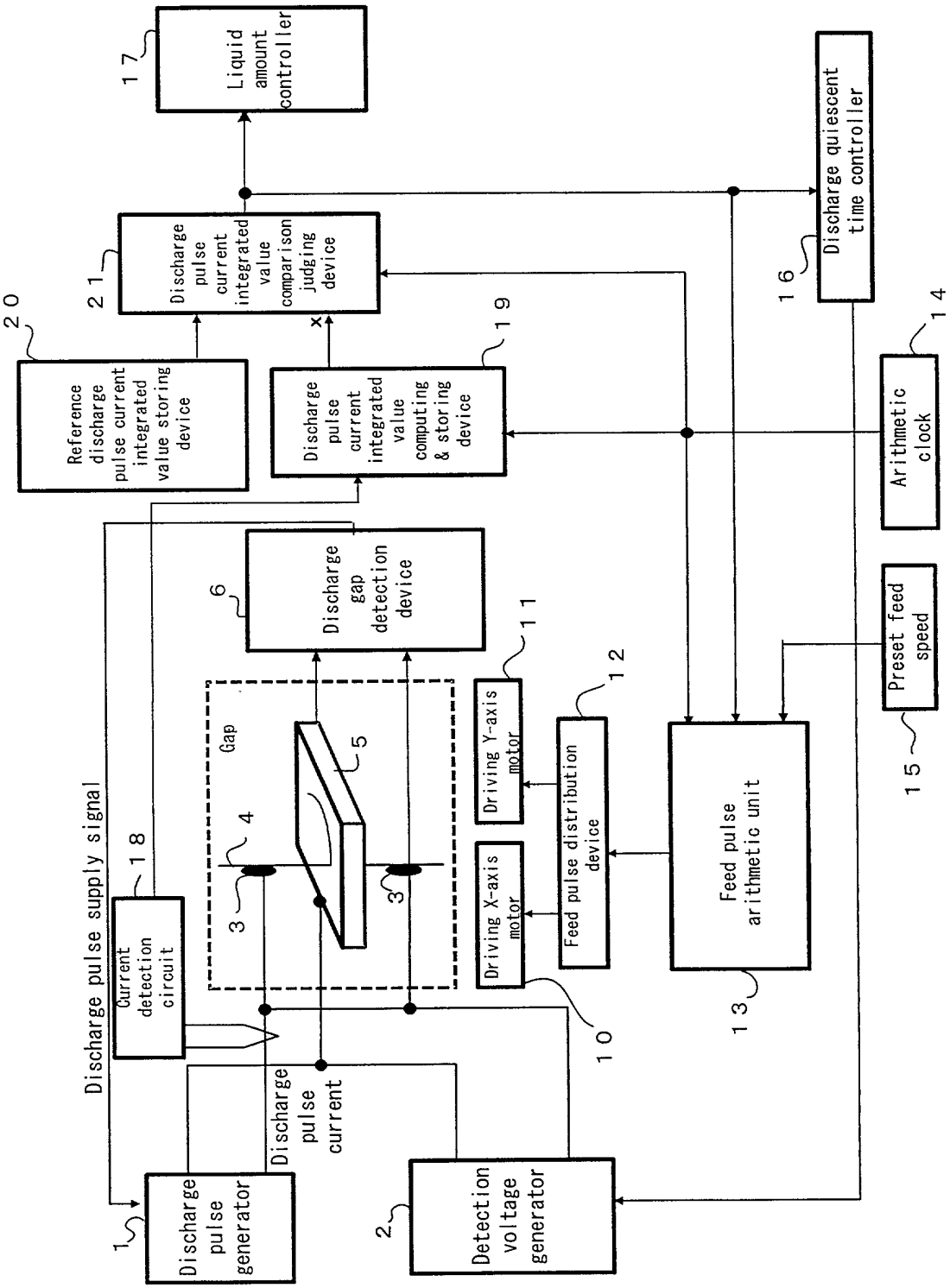
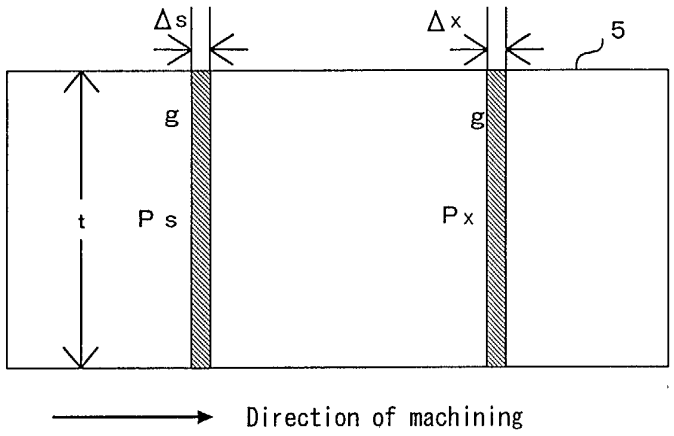

17
Liquid amount controller
21
Discharge pulse current integrated value comparison judging device
16
Discharge quiescent time controller
20
Reference discharge pulse current integrated value storing device
19
Discharge pulse current integrated value computing & storing device
14
Arithmetic clock
6
Discharge gap detection device
11
Driving Y-axis motor
12
Feed pulse distribution device
Feed pulse arithmetic unit
15
Preset feed speed
Gap
5
4
3
3
18
Current detection circuit
Discharge pulse supply signal
Driving X-axis motor
10
13
Discharge pulse current
1
Discharge pulse generator
2
Detection voltage generator

Fig. 3



P_s : Reference discharge pulse number per unit time T

P_x : Discharge pulse number per unit time T

Δ_s : Distance movable with reference speed discharge pulse number Ps

Δ_x : Distance movable with discharge pulse number Px per unit time T

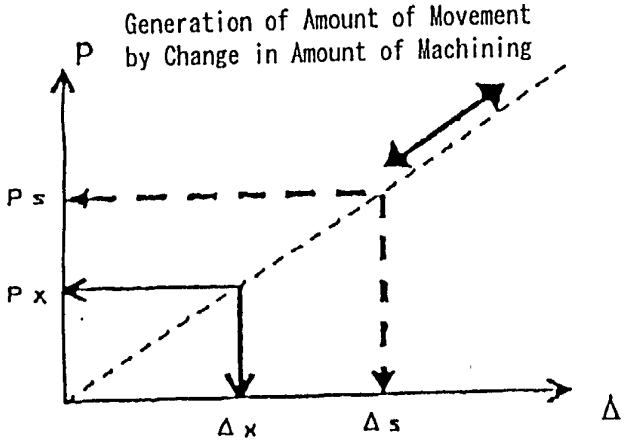
w : Amount of machining per discharge pulse

t : Plate thickness

g : Machining groove width

$P_s * w = \Delta_s * t * g$

$P_x * w = \Delta_x * t * g$



SPD Preset feed speed which is used as a reference

Δs : Distance movable per unit time T given by the preset feed speed SPD which is used as reference. Δs = SPD * T

Ps : Reference discharge pulse number

Px : Discharge pulse number per unit time T

Δx : Distance moveble with discharge pulse number Px per unit time T

Δx = Δs * Δx / Ps
=SPD * T * (Px / Ps)

Fig. 4

Fig. 5A

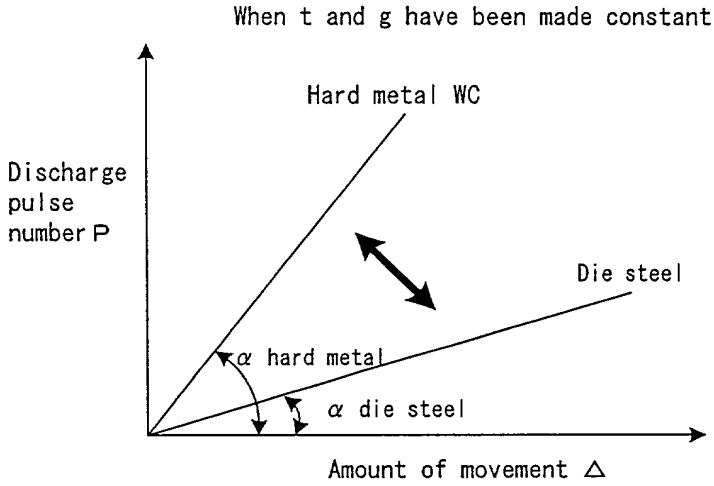


Fig. 5B

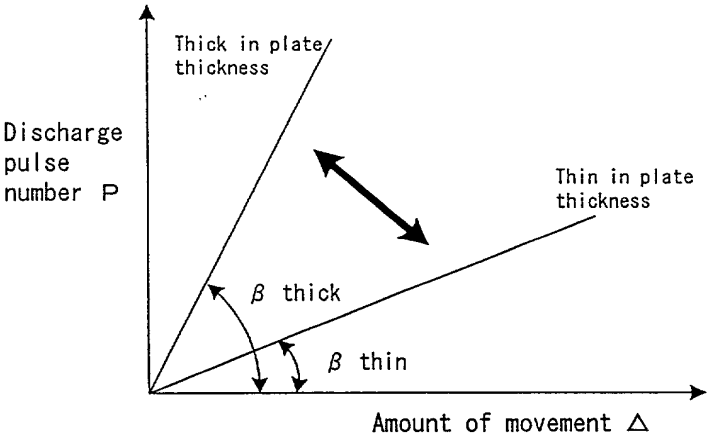


Fig. 5C

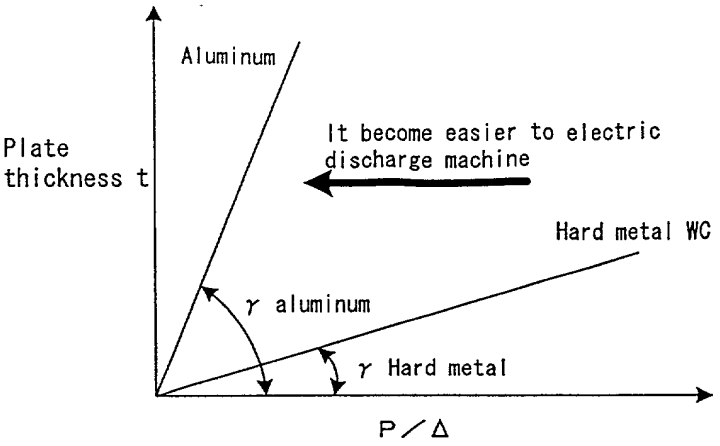


Fig. 6A

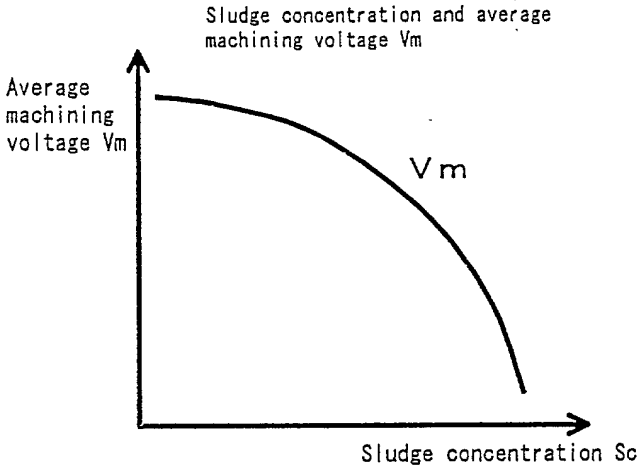

Sludge concentration and average machining voltage Vm
Average machining voltage Vm
Vm
Sludge concentration Sc

Fig. 6B

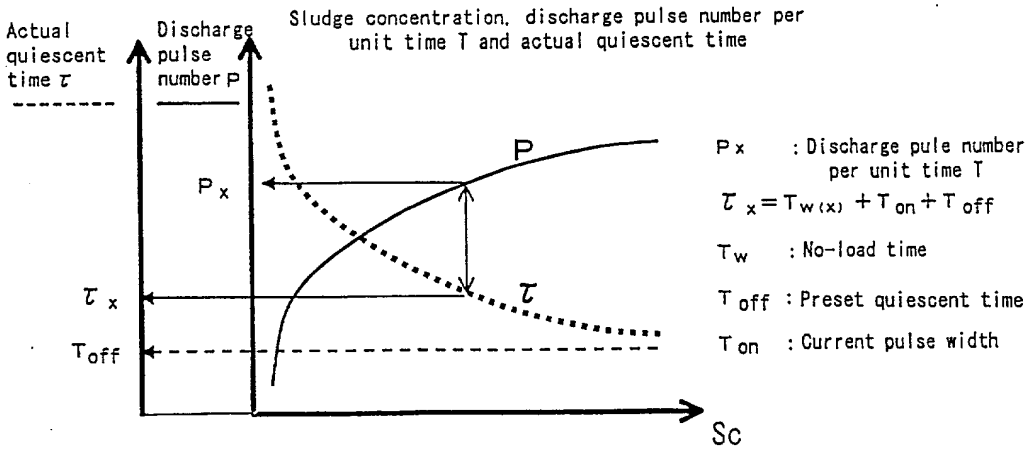

Actual quiescent time τ
Discharge pulse number P
Sludge concentration, discharge pulse number per unit time T and actual quiescent time
P
Px
τ x
τ
Toff
Sc
Px : Discharge pule number per unit time T
τ x = Tw(x) + Ton + Toff
Tw : No-load time
Toff : Preset quiescent time
Ton : Current pulse width

Fig. 7A

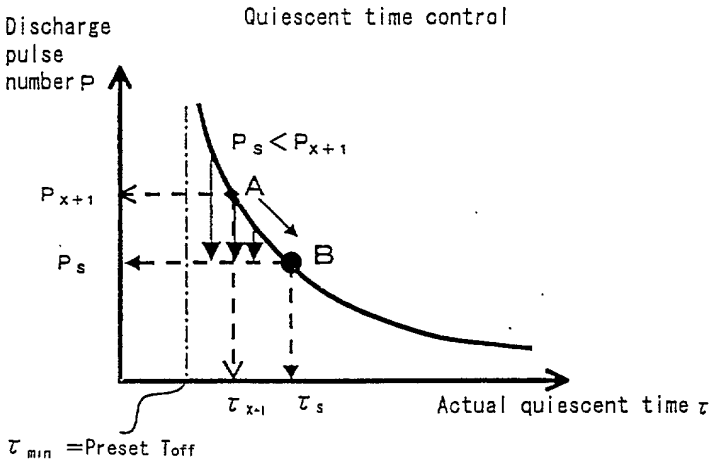

Quiescent time control
Discharge pulse number P
$P_s < P_{x+1}$
P_{x+1}
A
P_s
B
τ_{x-1}
τ_s
Actual quiescent time τ
τ_{min} =Preset Toff

Fig. 7B

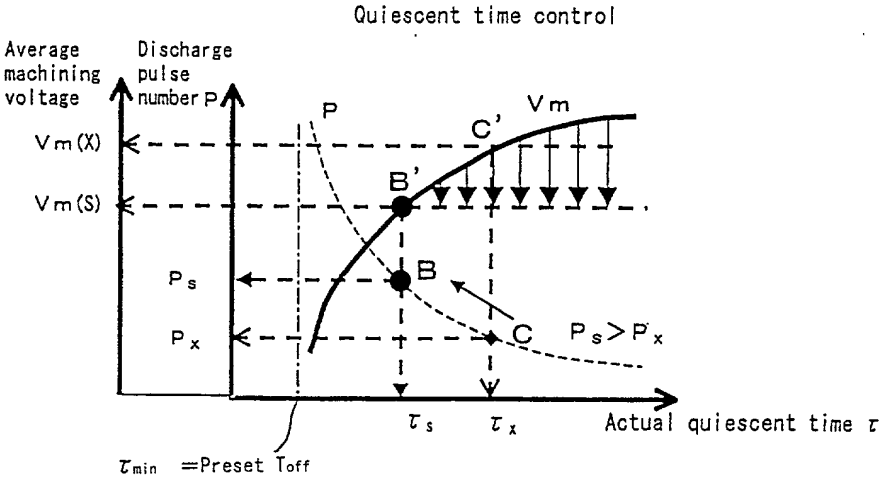
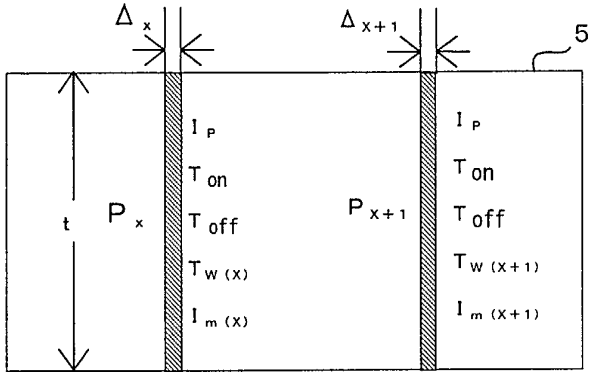

Quiescent time control
Average machining voltage
Discharge pulse number P
P
Vm
C'
Vm(X)
B'
Vm(S)
P_s
B
P_x
C
$P_s > P_x$
τ_s
τ_x
Actual quiescent time τ
τ_{min} =Preset Toff

Fig. 8



I : Current peak value (A)

T_{on} : Current pulse width (μ s)

T_{off} : Quiescent time (μ s)

$T_{W(x)}$ 、 $T_{W(x+1)}$: Average non-load time per unit time T (μ s)

$I_{m(x)}$ 、 $I_{m(x+1)}$: Average machining current (A) per unit time T

Δ_x : Distance movable with discharge pulse number Px per unit time T

Δ_{x+1} : Distance movable with discharge pulse number Px+1 per unit time T

g : Machining groove width (mm)

t : Plate thickness (mm)

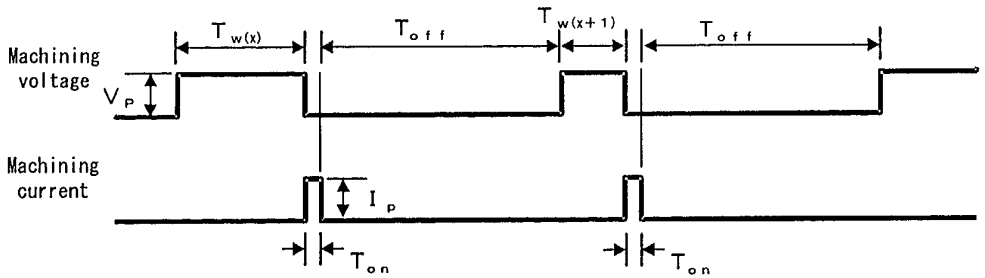


Fig. 9

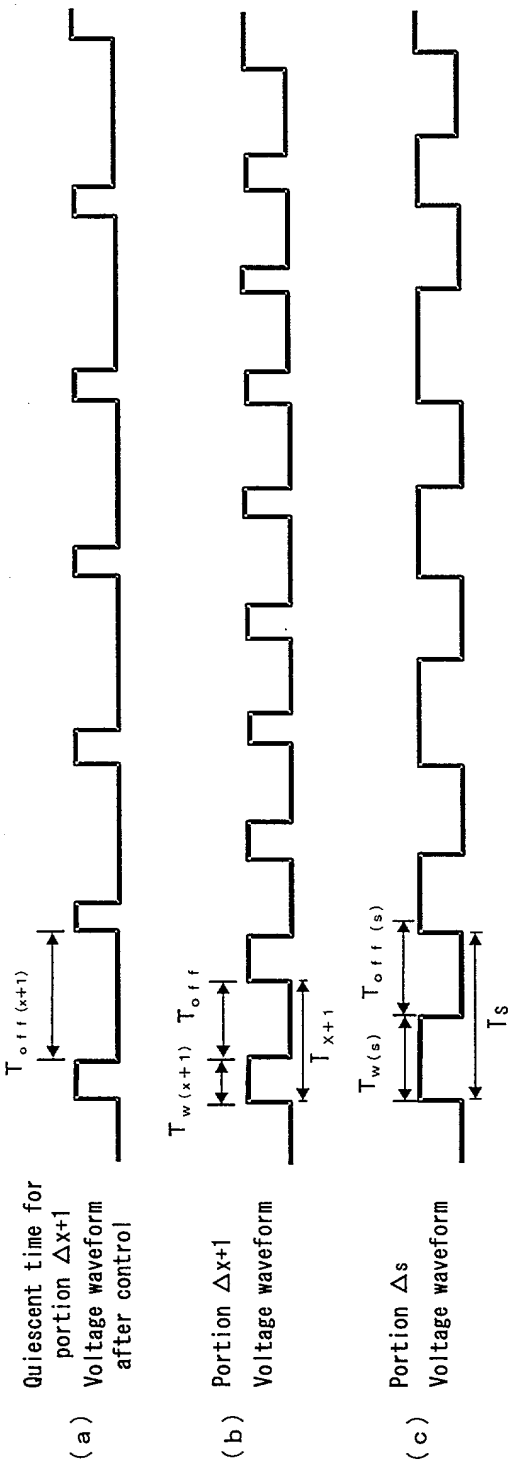
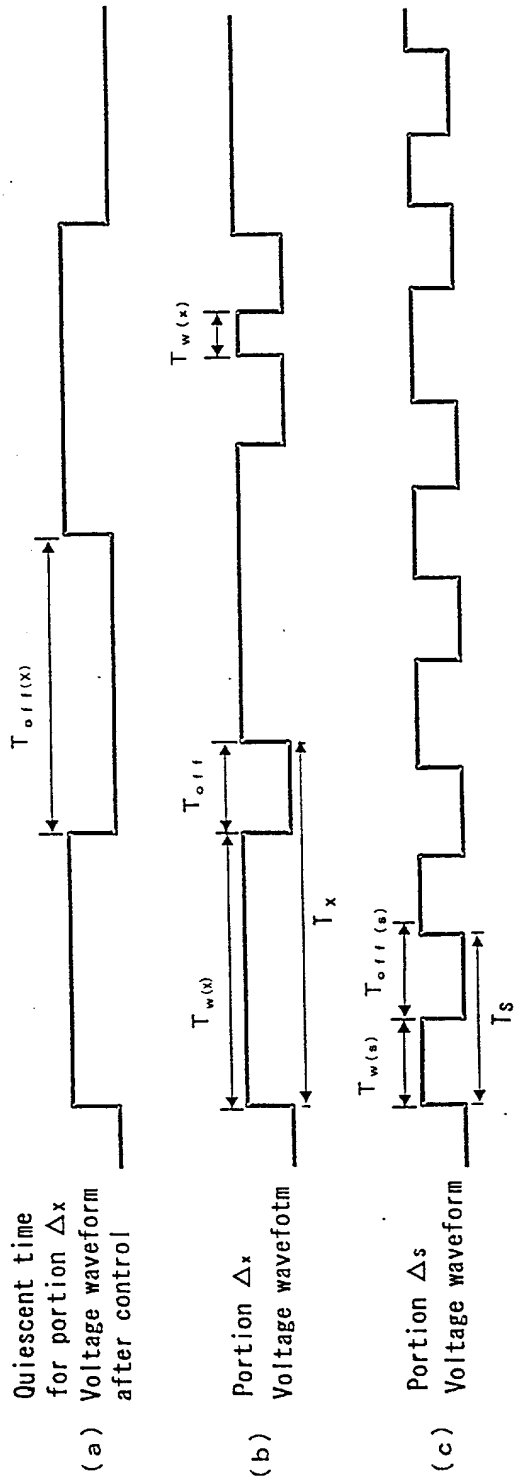
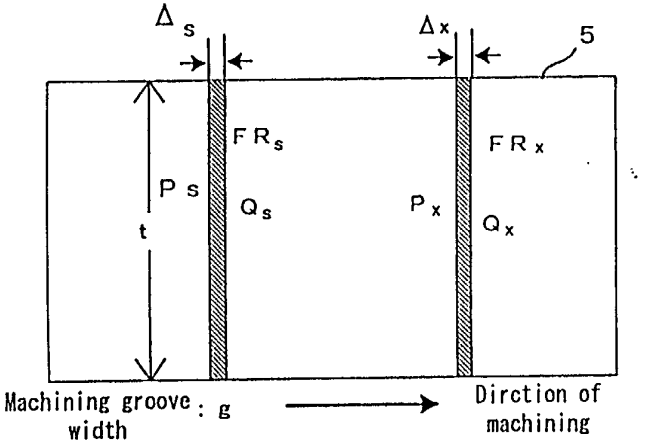

(a) Quiescent time for portion Δx+1 Voltage waveform after control
$T_{off(x+1)}$
(b) Portion Δx+1 Voltage waveform
$T_{w(x+1)}$ T_{off}
T_{X+1}
(c) Portion Δs Voltage waveform
$T_{w(s)}$ $T_{off(s)}$
T_S

Fig. 10


(a) Voltage waveform after control
Quiescent time for portion Δx
$T_{off(x)}$
(b) Voltage wavefotm
Portion Δx
$T_{w(x)}$
T_{off}
T_x
(c) Voltage waveform
Portion Δs
$T_{w(s)}$
$T_{off(s)}$
T_s



Δ_s : Distance movable with discharge pulse number Ps per unit time T

Δ_x : Distance movable with discharge pulse number Px per unit time T

g : Machining groove width (mm)

t : Plate thickness (mm)

w : Amount of machining per discharge pulse

Q_s : Amount of machining to be removed by reference discharge pulse number Ps ∝ amount of sludge to be discharged by preset amount of liquid FRs

Qx : Amount of machining to be removed by discharge pulse number Px per unit time T ∝ amount of sludge to be discharged by amount of liquid FRx

Fig. 12

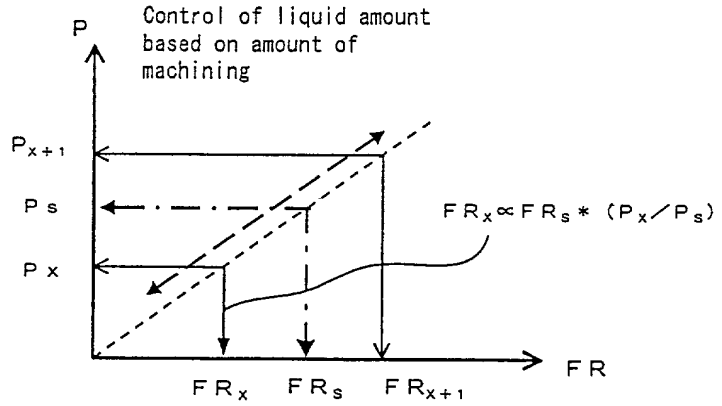

P
Control of liquid amount based on amount of machining
P_{x+1}
Ps
Px
$FR_x \propto FR_s * (P_x / P_s)$
FR
FR_x
FR_s
FR_{x+1}

Fig. 13

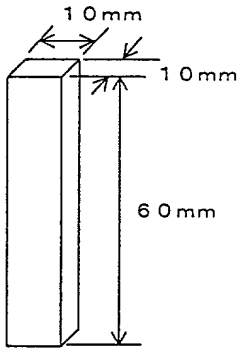

10mm
10mm
60mm

Fig. 14

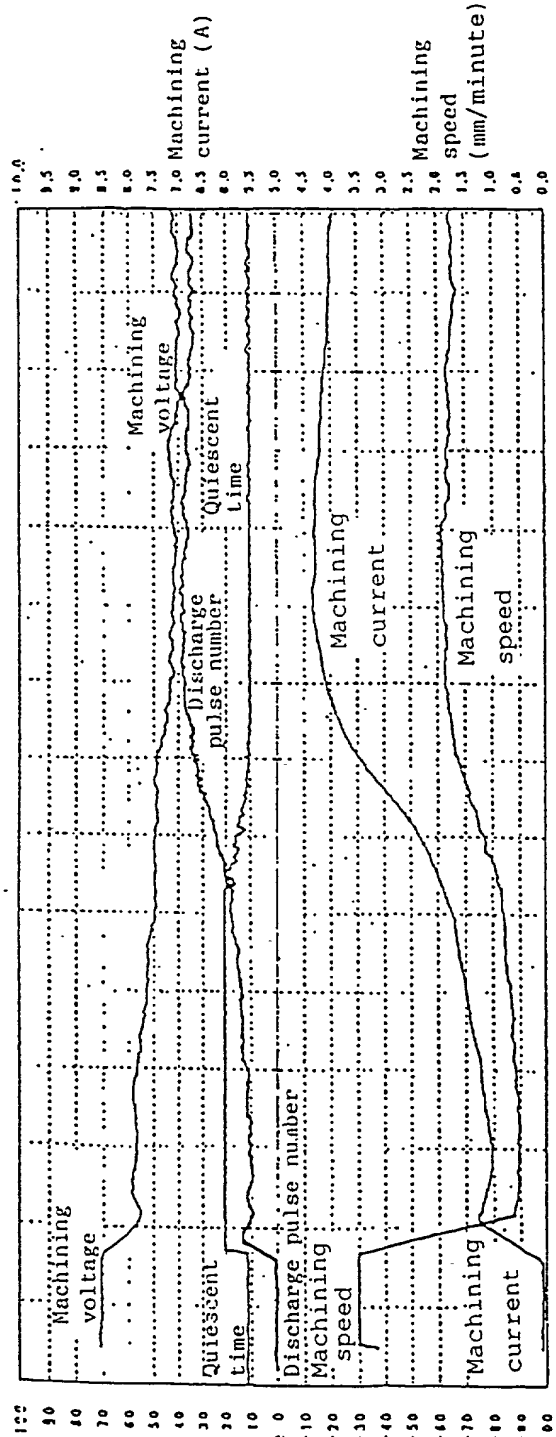

Machining voltage
Discharge pulse number
Quiescent time
Machining speed
Machining current
Machining elapsed time (10 seconds/div)
Discharge pulse number
Quiescent time (μ second)
Machining voltage (v)
Machining current (A)
Machining speed (mm/minute)

Fig. 15

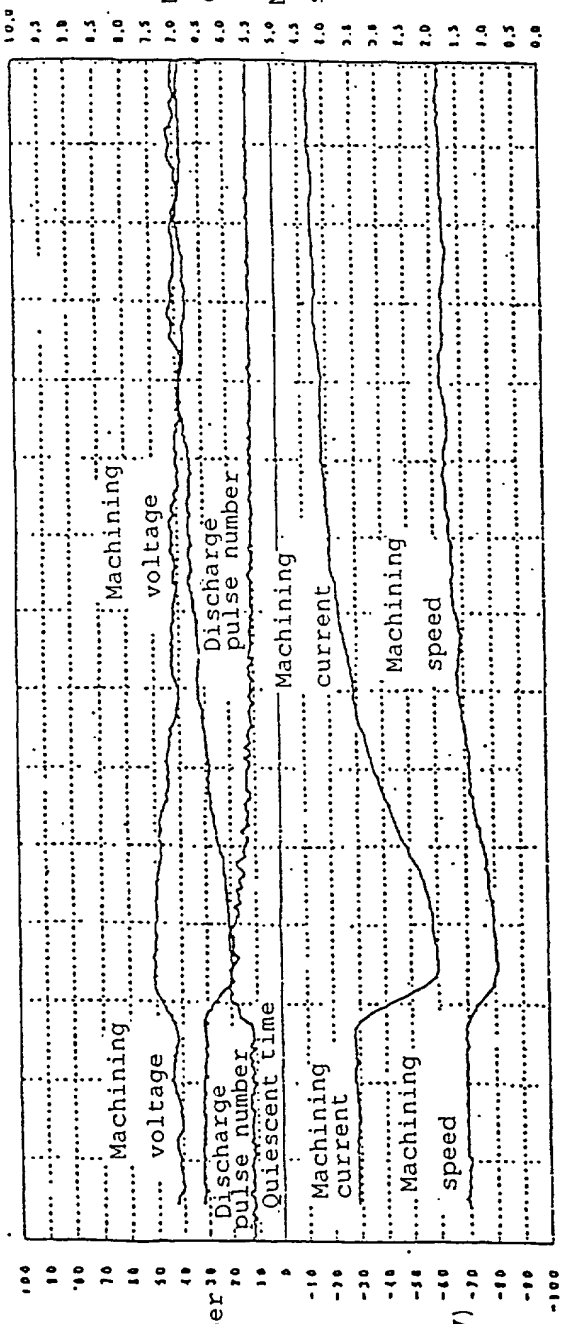

Machining voltage
Discharge pulse number
Quiescent time
Machining current
Machining speed
Machining elapsed time (10 seconds/div)
Discharge pulse number
Machining voltage (V)
Quiescent time (μ second)
Machining current (A)
Machining speed (mm/minute)

Fig. 16

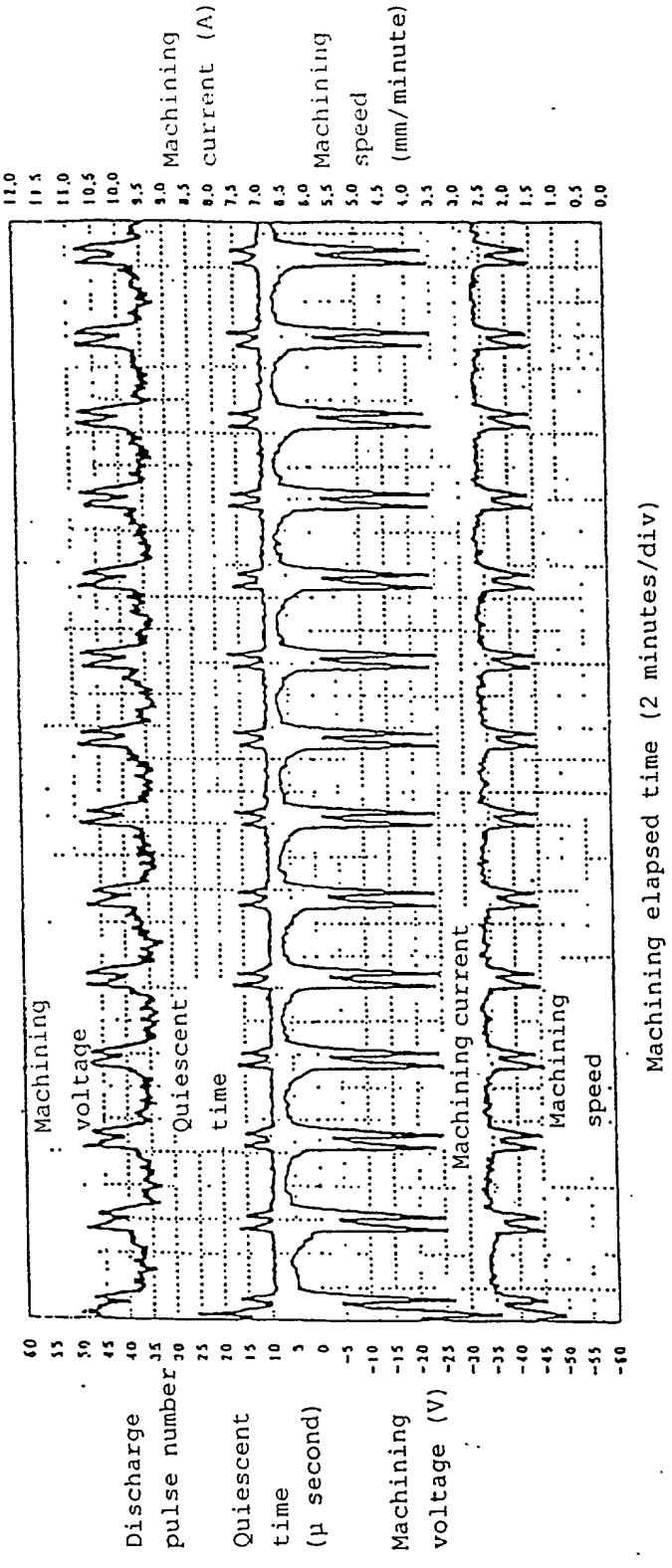
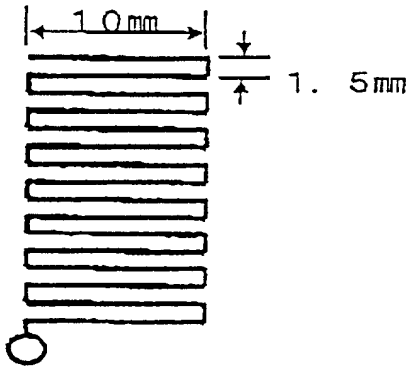

Machining voltage
Quiescent time
Machining current
Machining speed
Discharge pulse number
Quiescent time (μ second)
Machining voltage (V)
Machining current (A)
Machining speed (mm/minute)
Machining elapsed time (2 minutes/div)

Fig. 17



Machining start

Fig. 18

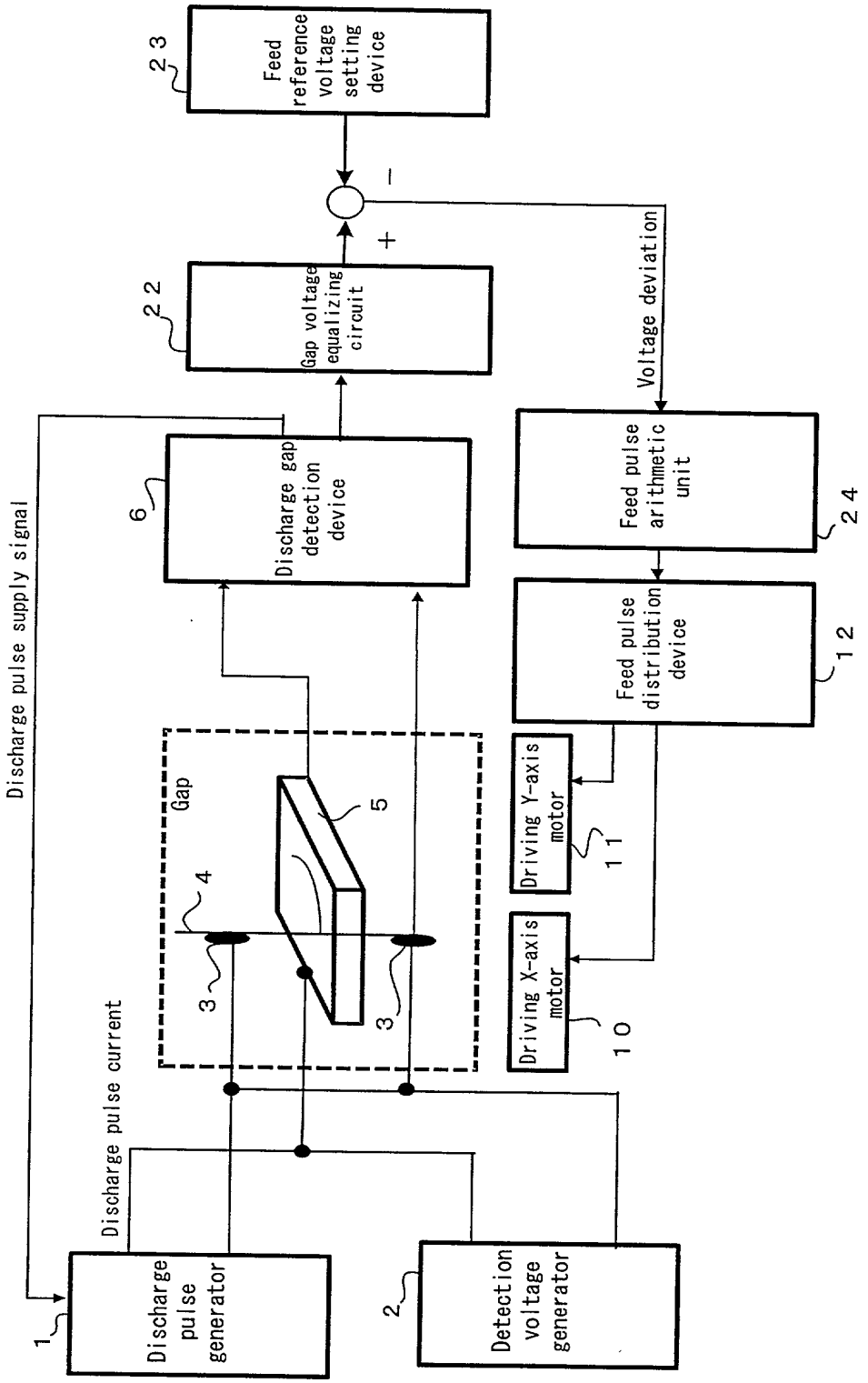
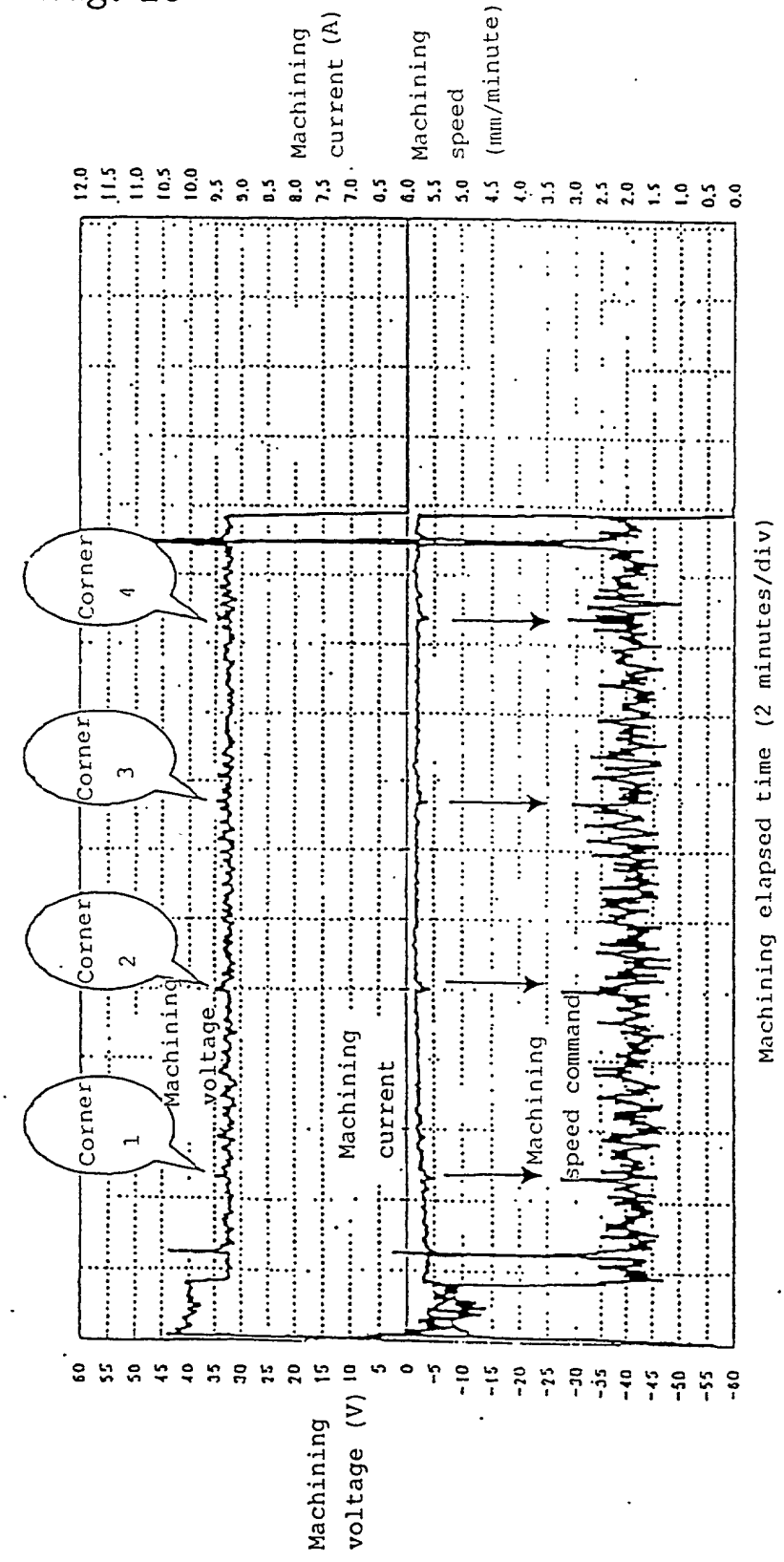

Feed reference voltage setting device
23
Gap voltage equalizing circuit
22
Discharge gap detection device
6
Feed pulse arithmetic unit
24
Feed pulse distribution device
12
Driving Y-axis motor
11
Driving X-axis motor
10
Voltage deviation
Discharge pulse supply signal
Discharge pulse current
Gap
3
4
5
Discharge pulse generator
1
Detection voltage generator
2
+
−

Fig. 19


Corner 1
Corner 2
Corner 3
Corner 4
Machining voltage
Machining current
Machining speed command
Machining voltage (V)
Machining current (A)
Machining speed (mm/minute)
Machining elapsed time (2 minutes/div)